Jet Propulsion Laboratory
California Institute of Technology

Stability and Targeting in Dawn's Final Orbit

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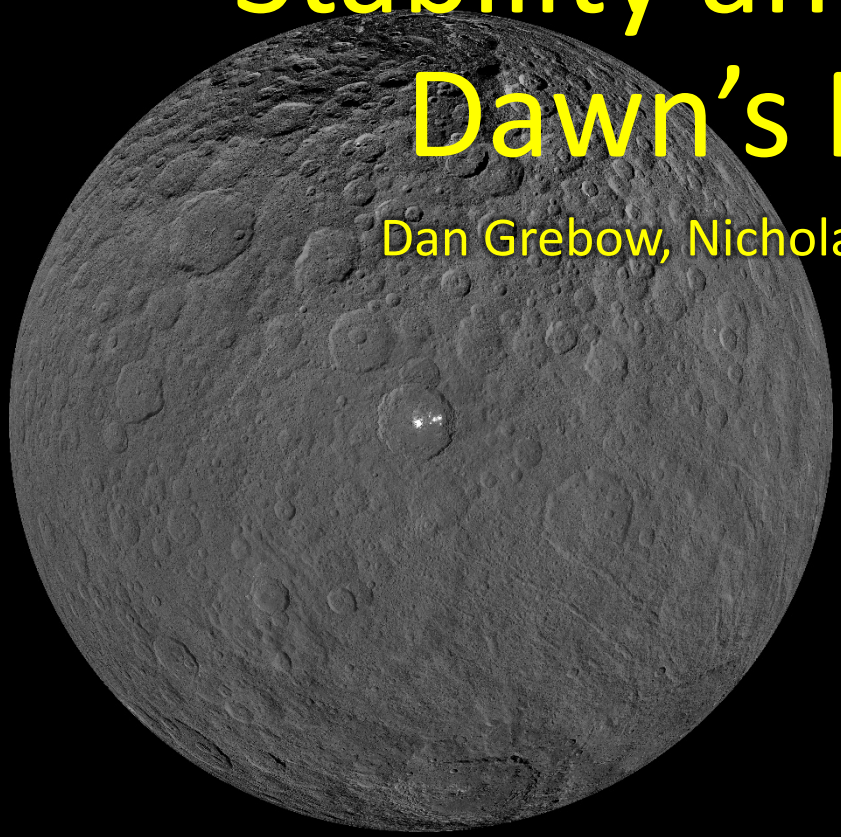
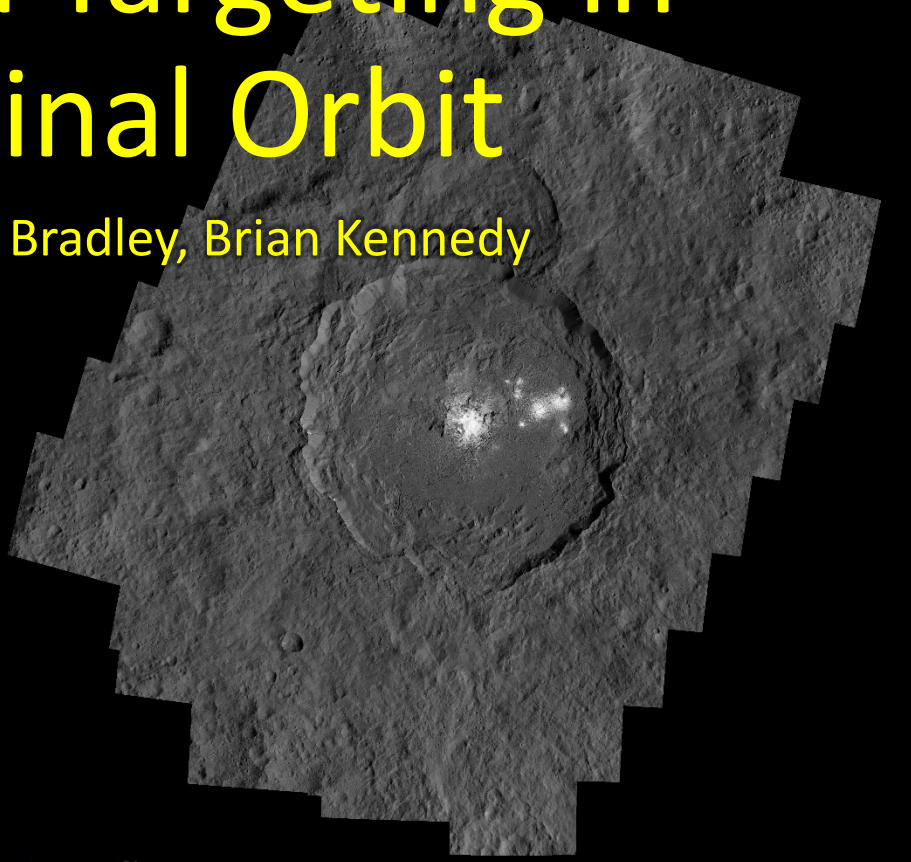
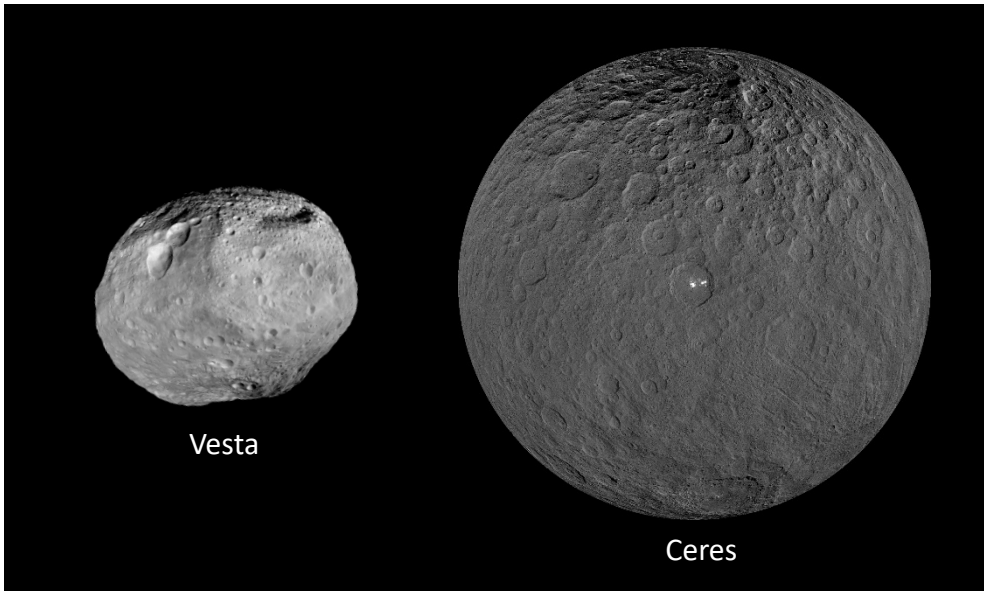
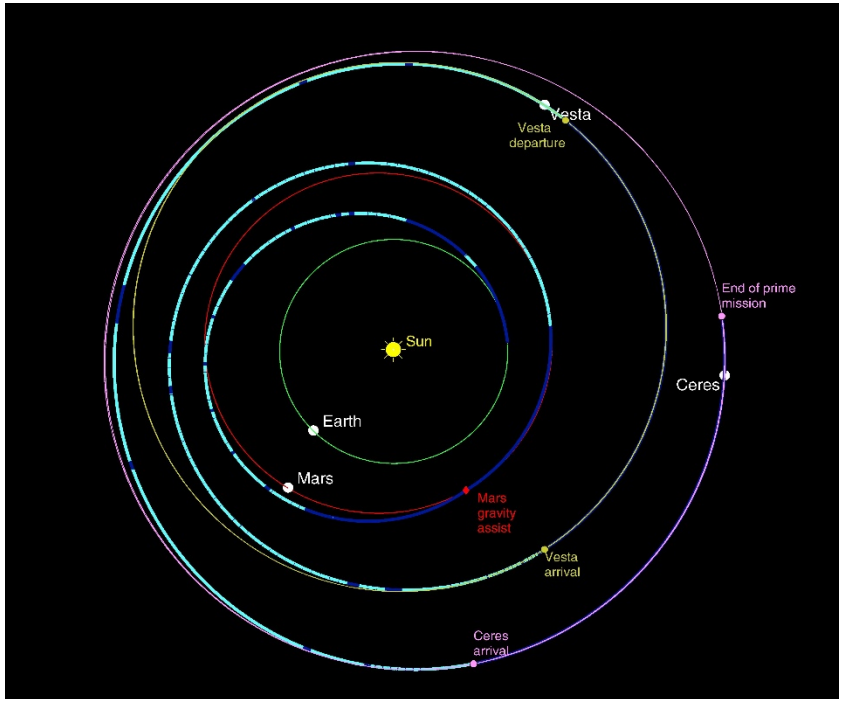




Dawn: NASA Discovery Mission

- Increase understanding of physical and chemical conditions and processes acting during solar system's epoch of planet formation
- Investigate two largest objects in main asteroid belt: Vesta and Ceres
- Orbit Vesta and Ceres acquiring imaging data, spectra, and gravity measurements

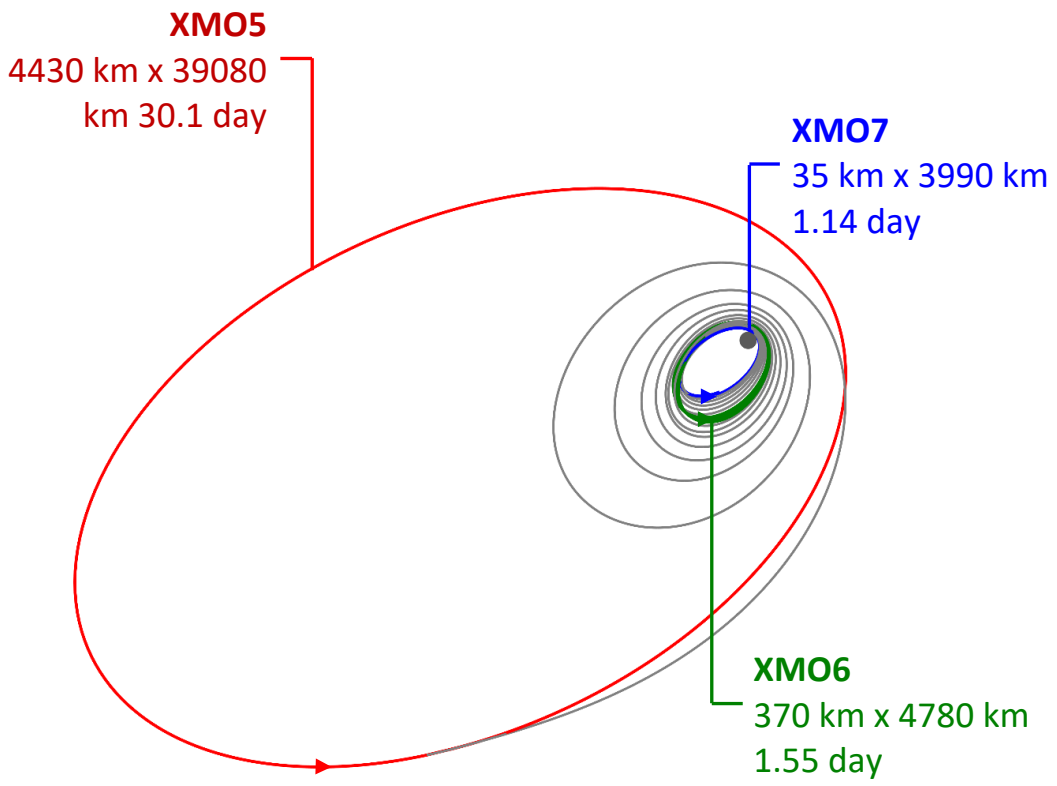




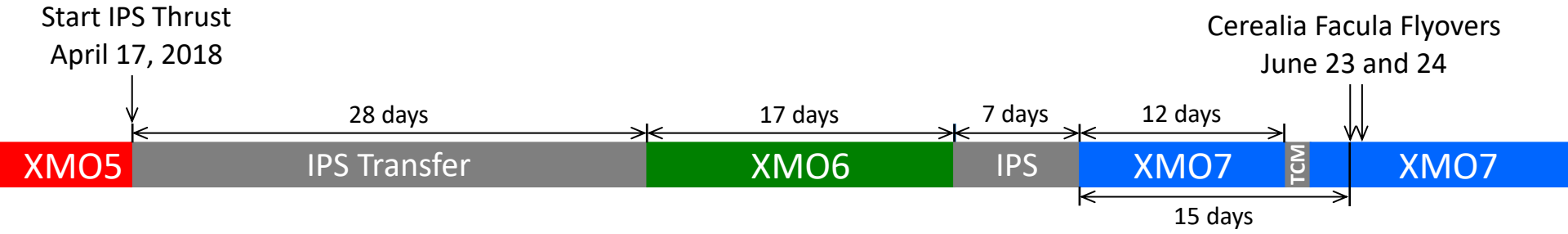
Dawn Mission Overview:

- Sept. 27, 2007: Launch
- Feb. 2009: Mars gravity assist
- May 2011 – Sept. 2012: Vesta campaign
- March 2015: Ceres arrival
- June 30, 2016: End prime mission
- July 2016 – Oct. 2017: XM1
- **Oct. 2017 – Oct. 2018: XM2**

Second Extended Mission (XM2)



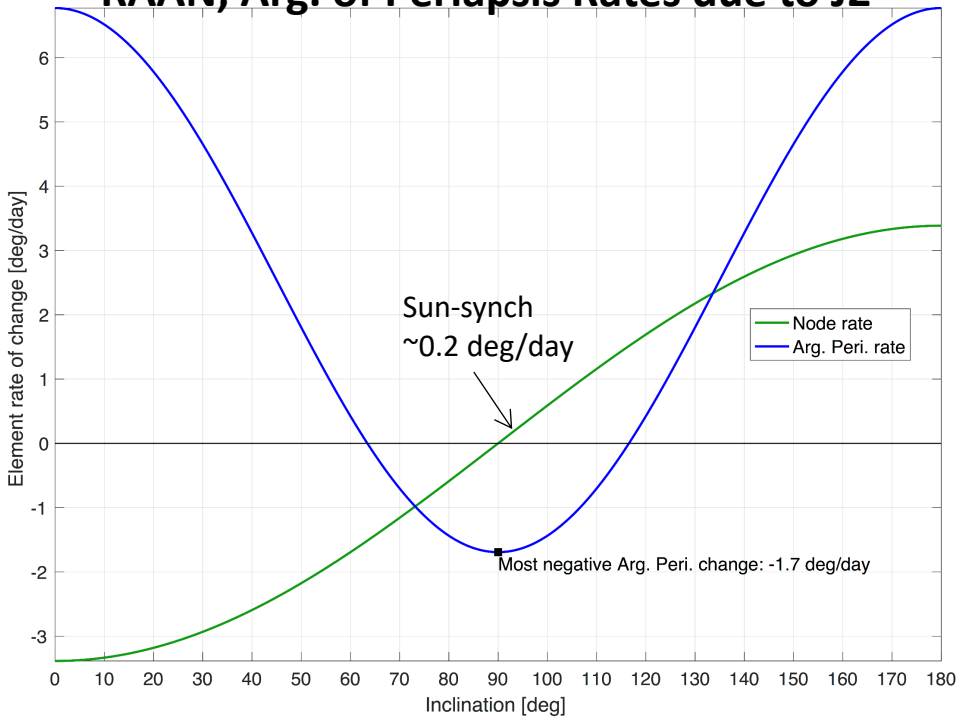
- XMO5: Collect data to reduce noise of Ceres nuclear spectra
- XMO6: Obtain low-altitude VIR coverage of southern hemisphere and acquire VIR spectra for northern wall of Juling Crater
- XMO7: Improve resolution of nuclear spectra and obtain high resolution imagery, particularly for Cerealia Facula



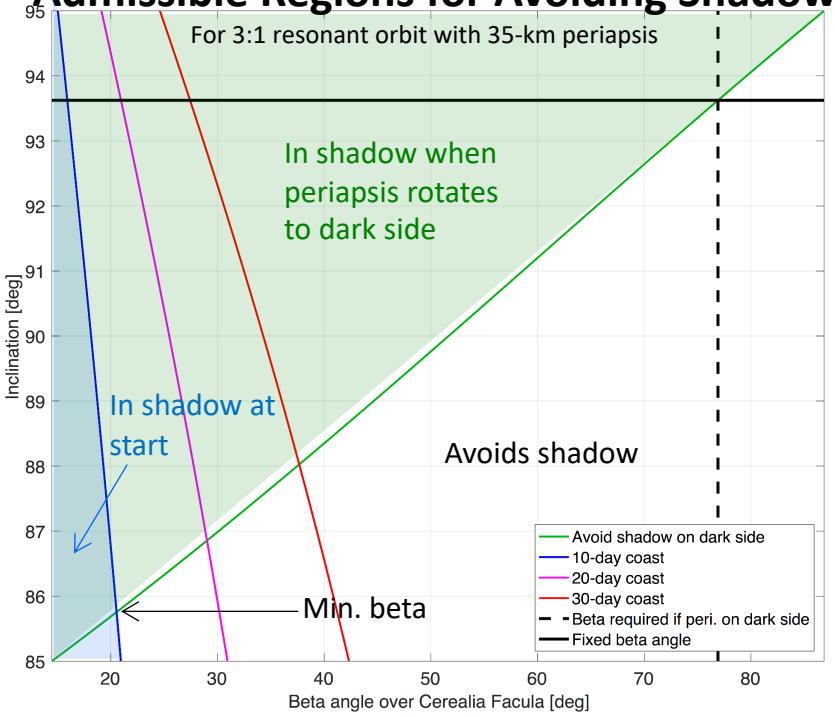
XMO7 Mission Design Objectives

- 3:1 resonant orbit, sub-spacecraft periapsis longitude over same part of Ceres
- Fly over Cerealia Facula at periapsis for imaging
- Periapsis as low as possible but does not crash 50 years after loss of spacecraft
- Spacecraft does not go into shadow during first 100 days of orbit

RAAN, Arg. of Periapsis Rates due to J2



Admissible Regions for Avoiding Shadow

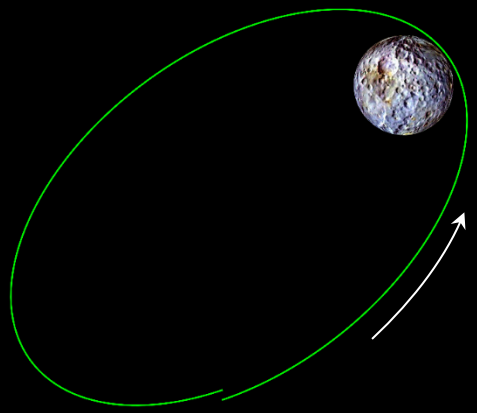


XMO7

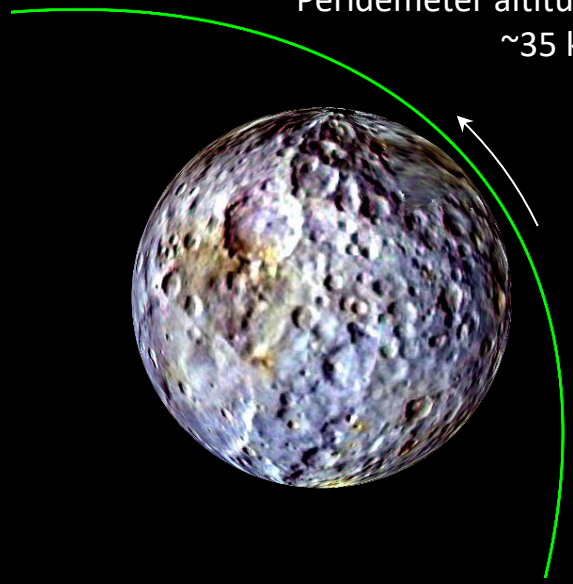
Orbital parameters:
Period = 27.2 hr
Eccentricity = 0.8
Inclination = 84.3°
Initial Beta = 27.1°

Peridemeter 13 and 14 designed to fly over Cerealia Facula

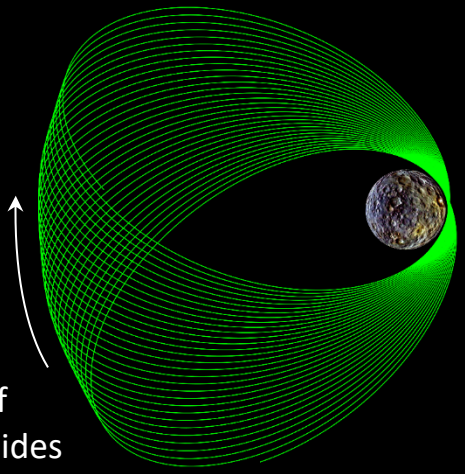
3:1 resonant orbit



Peridemeter altitude ~35 km



First 30 science orbits



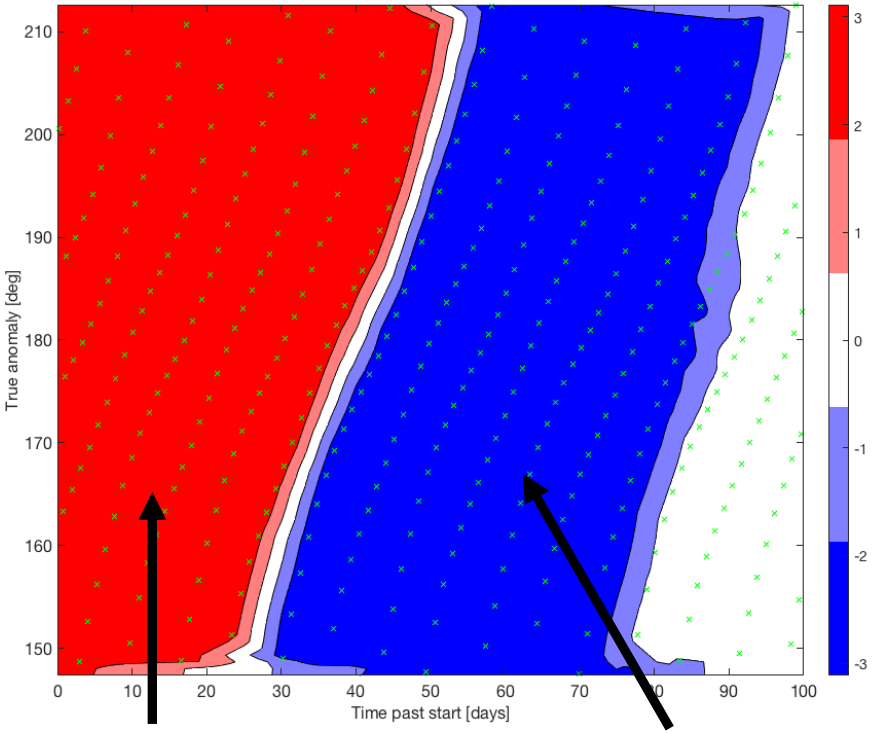
Natural rotation of line of apsides

- J2 causes line of apsides to rotate 1.7° per day
  - → Periapsis latitude shifts 1.9° per orbit
  - → Periapsis never directly over same place
- J2 stabilizes solar gravity perturbations
- End-of-Mission occurs in this orbit when spacecraft runs out of hydrazine for attitude control (October 31, 2018)

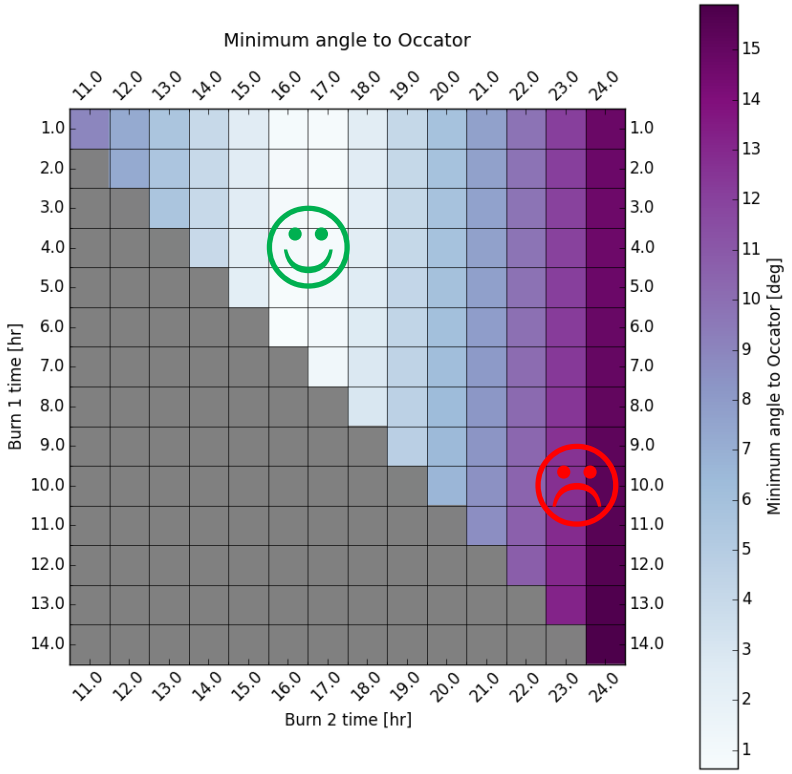
Modeling Expected RCS Activity in XMO7

RCS perturbations large source of uncertainty

ACS-simulated RCS Thrust Data

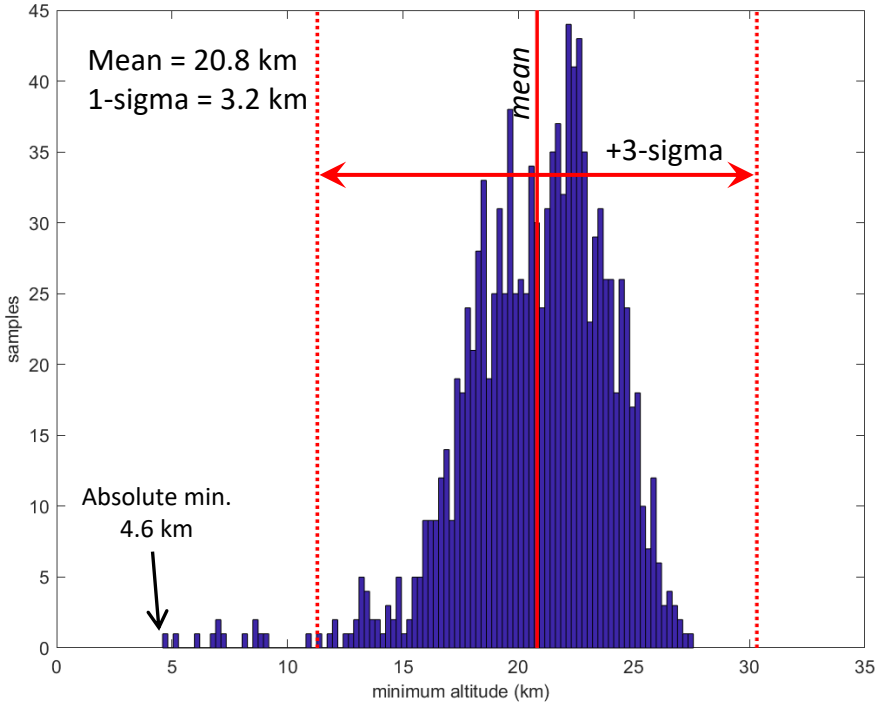


RCS Slew Times Relative to Periapsis



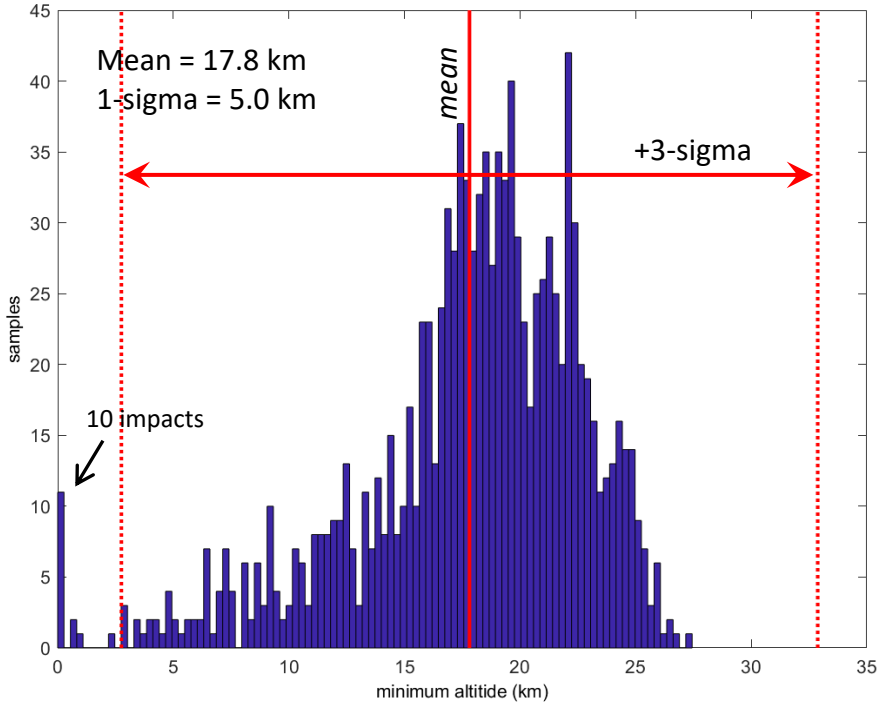
Orbital Lifetime Histograms of Minimum Spacecraft Altitude from Ceres' Surface

20-year Monte Carlo Study



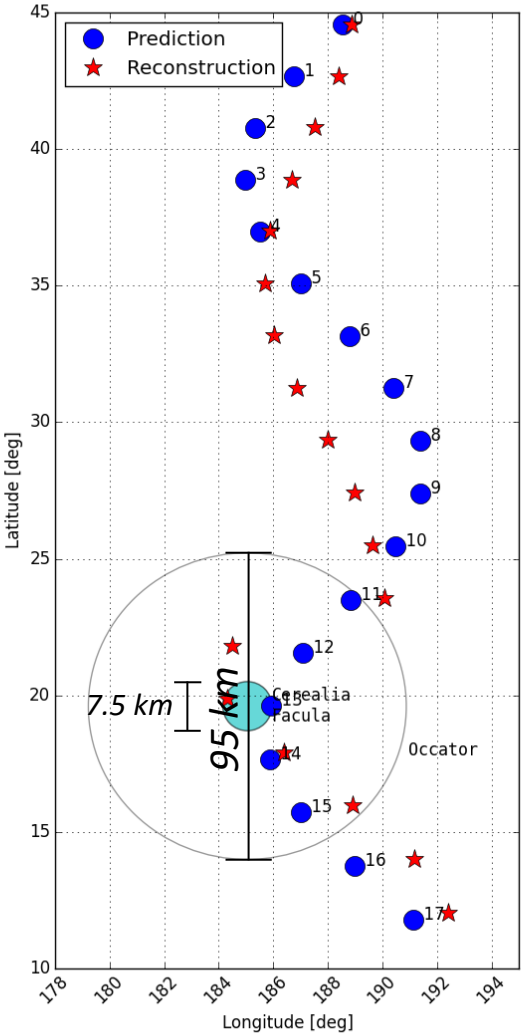
None of the 1,150 samples impact Ceres within 20 years

50-year Monte Carlo Study

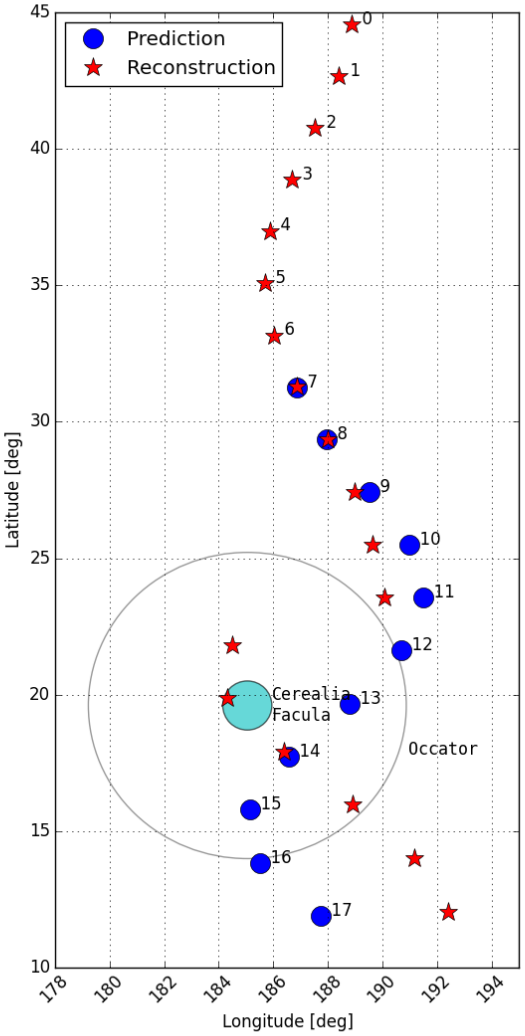


99.1% of samples do not impact Ceres in 50 years

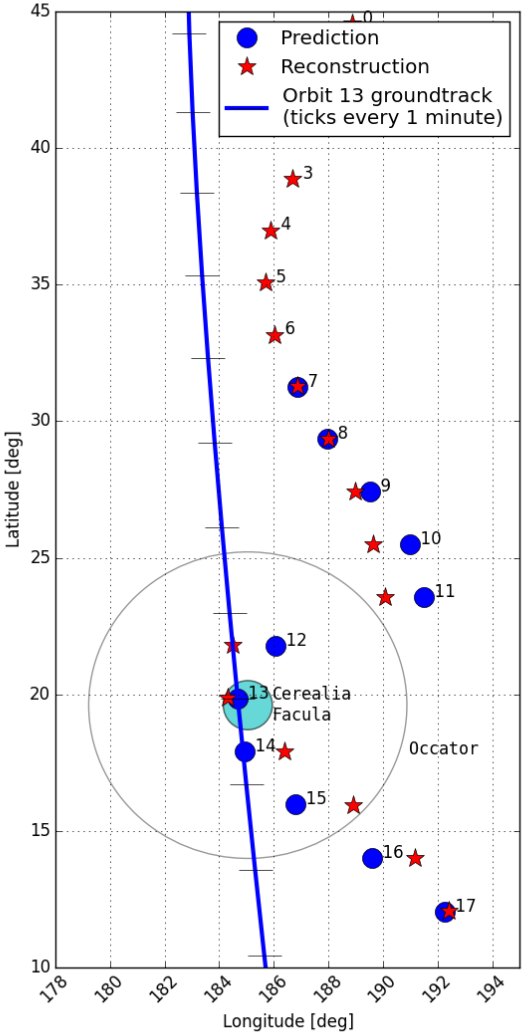
Reconstructed Vs. Predicted Performance



Prediction at time of Orbit Insertion

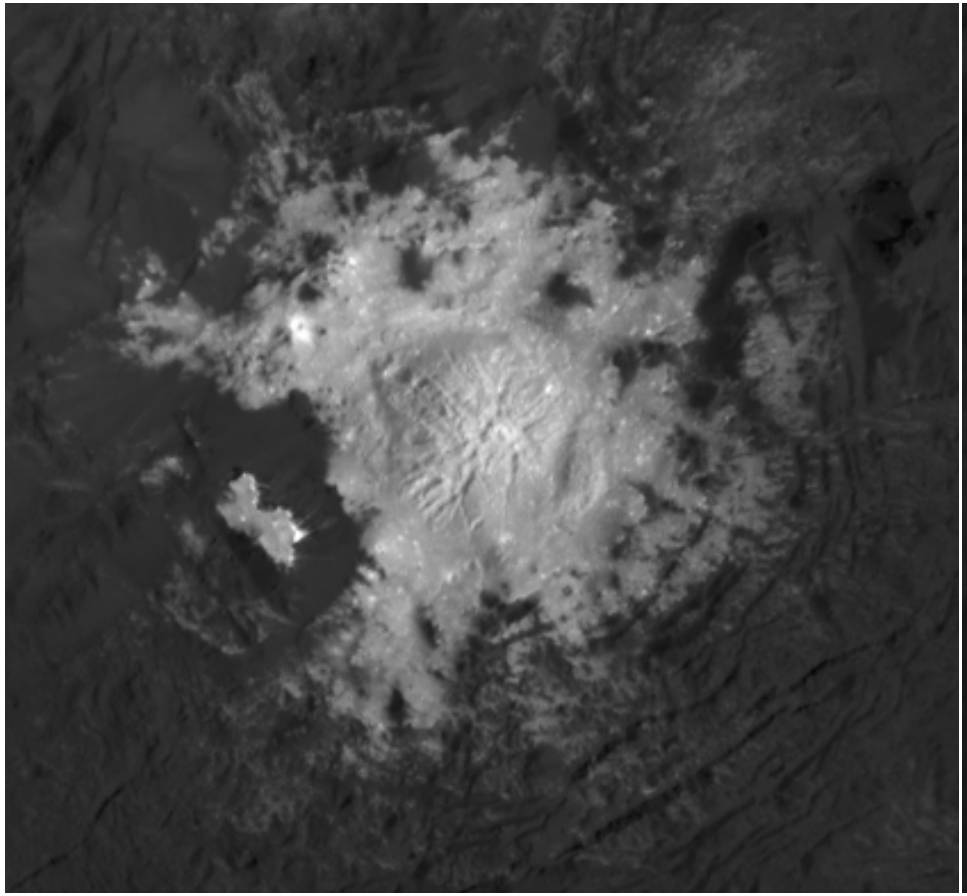


Prediction at TCM Design assuming no TCM

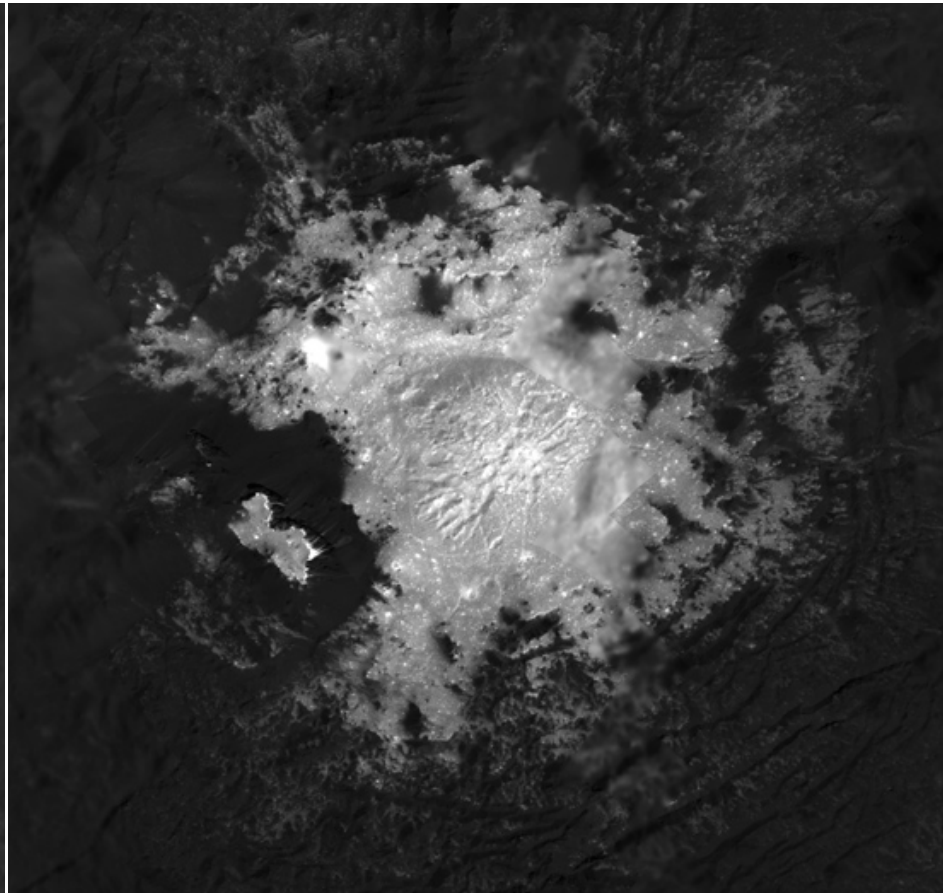


Prediction at TCM Design including TCM

Mosaics of Cerealia Facula



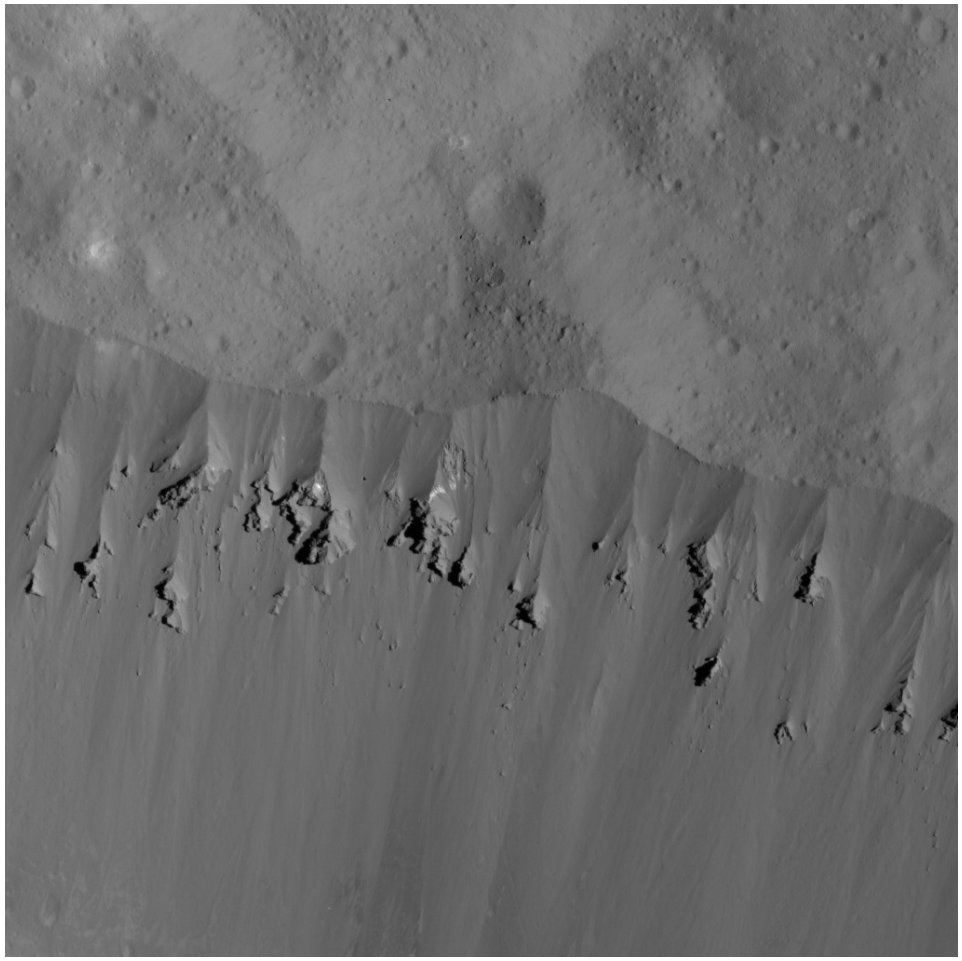
LAMO



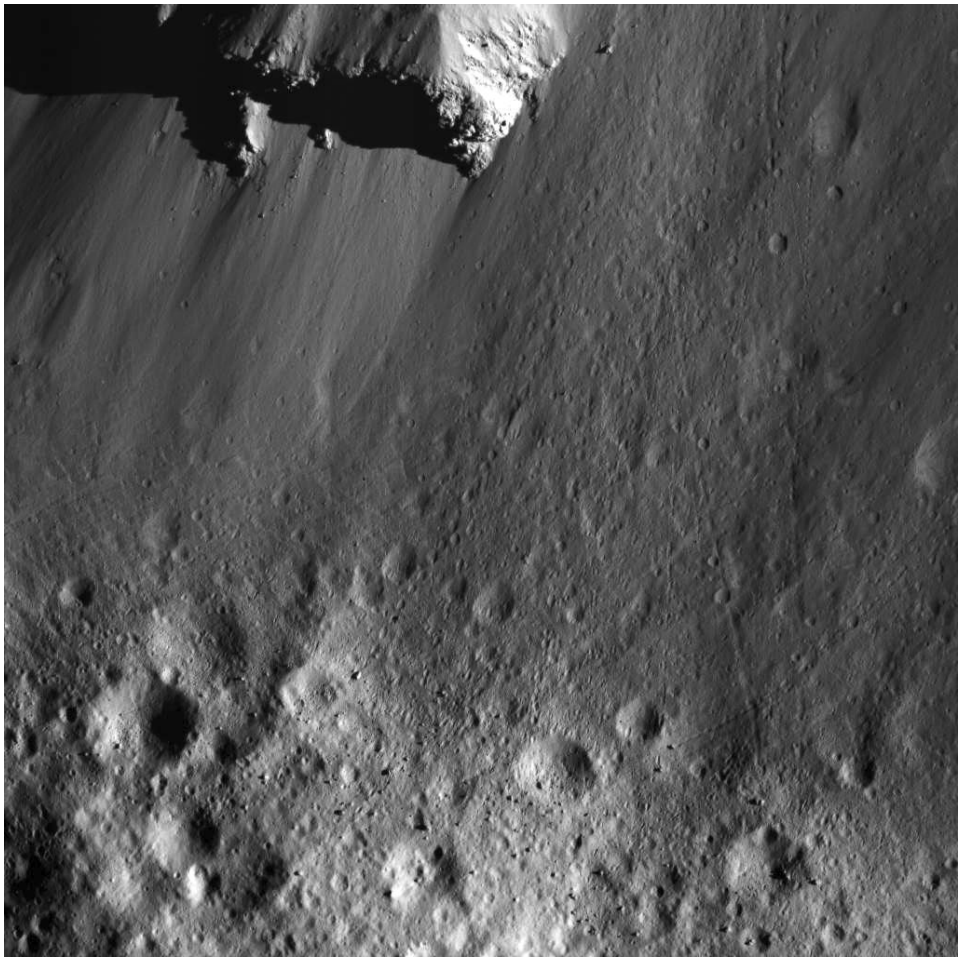
XMO7

Other XM2 Images

Eastern Wall of Occator Crater Landslides



Urvara Crater (45.7^{o}S) & Falling Boulders



Conclusion

- XM2 was challenging to design and navigate
  - Final orbit is highly eccentric with low 35-km periapsis and high argument of periapsis rate due to J2
  - XMO7 targeted flyover at periapsis to image Cerealia Facula with lowest possible beta angle
- The team demonstrated post-mission orbital lifetime greater than 50 years, complying with planetary protection's 20-yr requirement
- Flyover of Cerealia Facula was a complete success and all science objectives for XM2 were satisfied
- Loss of communications with the spacecraft occurred on Oct. 31, 2018, near the expected time when usable hydrazine would be expended
- Latest OD state and ballistic propagations well within bounds of Monte Carlo planetary protection analysis